Veterinary
Anaesthesia and Analgesia
Formerly the Journal of Veterinary Anaesthesia

Veterinary Anaesthesia and Analgesia, 2011, **38,** 344–351 doi:10.1111/j.1467-2995.2011.00627.x

RESEARCH PAPER

Effect of fentanyl target-controlled infusions on isoflurane minimum anaesthetic concentration and cardiovascular function in red-tailed hawks (*Buteo jamaicensis*)

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Abstract

Objective To determine the impact of three different target plasma concentrations of fentanyl on the minimum anaesthetic concentration (MAC) for isoflurane in the red-tailed hawk and the effects on the haemodynamic profile.

Study design Experimental study.

Animal population Six healthy adult red-tailed hawks (*Buteo jamaicensis*) of unknown sex with body weights (mean ± SD) of 1.21 ± 0.15 kg.

Methods This study was undertaken in two phases. In the first phase anaesthesia was induced with isoflurane in oxygen via facemask and maintained with isoflurane delivered in oxygen via a Bain circuit. Following instrumentation baseline determination of the MAC for isoflurane was made for each animal using the bracketing method and a supramaximal electrical stimulus. End-tidal isoflurane concentration (E′Iso) was then set at 0.75 × MAC and after an appropriate equilibration period a bolus of fentanyl (20 μg kg^{-1}) was administered intravenously (IV) in order to determine the pharmacokinetics of fentanyl in the isoflurane-anaesthetized red-tailed hawk. During the second phase anaesthesia was induced in a similar manner and E′Iso was set at 0.75 × MAC for each individual. Fentanyl was infused IV to achieve target plasma concentrations between 8 and 32 ng mL^{-1}. At each fentanyl plasma concentration, the MAC for isoflurane and cardiovascular variables were determined. Data were analyzed by use of repeated-measures ANOVA.

Results Mean ± SD fentanyl plasma concentrations and isoflurane MACs were 0 ± 0, 8.51 ± 4, 14.85 ± 4.82 and 29.25 ± 11.52 ng mL^{-1}, and 2.05 ± 0.45%, 1.42 ± 0.53%, 1.14 ± 0.31% and 0.93 ± 0.32% for the target concentrations of 0, 8, 16 and 32 ng mL^{-1}, respectively. At these concentrations fentanyl significantly ($p = 0.0016$) decreased isoflurane MAC by 31%, 44% and 55%, respectively. Dose had no significant effect on heart rate, systolic, diastolic or mean arterial blood pressure.

Conclusions and clinical relevance Fentanyl produced a dose-related decrease of isoflurane MAC

with minimal effects on measured cardiovascular parameters in red-tailed hawks.

Keywords avian, fentanyl, isoflurane, MAC, red-tailed hawk, target-controlled infusion.

Introduction

Raptors such as hawks and other birds of prey are presented frequently to avian veterinarians with injuries that require general anaesthesia for proper and humane treatment. General anaesthesia in birds is commonly accomplished by means of inhalant anaesthetics. Inhalant anaesthetic agents have the advantage of predictable and rapid changes in anaesthetic depth, as well as minimal or no metabolic breakdown. In addition, anaesthetic recovery is generally rapid and controlled because most modern inhalant agents have low blood solubility. However, inhalant anaesthetics are known to cause dose-dependent cardiovascular and respiratory depression (Pagel et al. 2009), which can be associated with perioperative morbidity and mortality. In mammals this problem is often countered with balanced anaesthetic techniques.

In humans and small animals, balanced anaesthesia may be accomplished by combining inhalant agents with opioids, local anaesthetics, NMDA antagonists and other techniques with the aim of improving hemodynamics by minimizing the necessary concentration of inhalant anaesthetics required to maintain an appropriate plane of general anaesthesia (Murphy & Hug 1982; Hall et al. 1987; McEwan et al. 1993; Ilkiw et al. 1994; Pypendop & Ilkiw 2005; Solano et al. 2006; Steagall et al. 2006; Ueyama et al. 2009).

Fentanyl, a synthetic mu-receptor agonist with a relatively short time to peak analgesic effect and a short duration of action when administered as a single intravenous (IV) bolus, has gained widespread popularity as an anaesthetic adjuvant. It is one of the most commonly used intraoperative opioid analgesics in human and small animal medicine. Intravenous administration of fentanyl has been reported to decrease the requirements for inhalation anaesthetics in humans, dogs, rats and pigs (Murphy & Hug 1982; McEwan et al. 1993; Moon et al. 1995; Criado & Gomez e Segura 2003). However, mu-opioid agonists (including fentanyl) have not been shown consistently to decrease effective dose requirements of inhaled anaesthetics in horses (Knych et al. 2009).

The minimum alveolar concentration of inhaled anaesthetic drugs has been used as the standard measure of anaesthetic potency for these agents in mammalian species and is the concentration that has a 50% probability of preventing gross purposeful movement in response to a supramaximal noxious stimulus (Merkel & Eger 1963; Eger et al. 1965; Quasha et al. 1980). Because birds do not have pulmonary alveoli, the term minimum anaesthetic concentration (MAC) refers to the minimum concentration of pulmonary (rather than alveolar) anaesthetic gas. The MAC of isoflurane in birds has only been determined for a few species (Ludders et al. 1988, 1989, 1990; Curro et al. 1994; Mercado et al. 2008).

The goals of this study were fourfold: 1) to determine the MAC of isoflurane in the red-tailed hawk (*Buteo jamaicensis*); 2) to determine the pharmacokinetics of IV administered fentanyl in isoflurane-anaesthetized red-tailed hawks; 3) to establish whether fentanyl has an isoflurane MAC-sparing effect in the red-tailed hawk; and 4) to elucidate whether fentanyl/isoflurane combinations result in an improved hemodynamic profile as compared to equipotent doses of isoflurane alone.

Materials and methods

Six healthy adult red-tailed hawks of unknown sex with body weights (mean ± SD) of 1.21 ± 0.15 kg were used for this study. Health status was determined by physical examination, complete blood count, serum biochemistry and faecal evaluation for endoparasites within 14 days prior to the start of the study. The subjects had previously been deemed unreleasable due to orthopedic injuries, visual deficits or beak malformations and were permanent residents of the California Raptor Center at the University of California, Davis. This protocol was approved by the University of California at Davis Institutional Animal Care and Use Committee. This study was undertaken in two phases.

Phase I

All birds were fasted overnight prior to being anaesthetized. A small amount of 2.5% lignocaine and 2.5% prilocaine cream (EMLA; AstraZeneca LP, DE, USA) was placed over the superficial ulnar artery bilaterally and the area was occluded with a 6–7 cm clear, self-adhesive bandage (Tegaderm; 3M Health Care, MN, USA) for 30 minutes prior to anaesthetic

